SUPPLEMENT.

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FORMING A COMPLETE RECORD OF THE PROCEEDINGS OF ALL PUBLIC COMPANIES.

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The Mines and Minerals of America.

No. II.

CANNEL COAL MINES OF KANAWHA, VIRGINIA.

Ranking next to the anthracite of Pennsylvania as a staple of national importance stands the cannel coal of Western Virginia and Kentucky. A great deal has been said and written on the abundance of this mineral as supposed to abound in these two States, but the public generally are nearly as far wide of the truth now as they were 10 years ago. Almost every landowner who finds a piece of loose cannel in one of the streams on his estate immediately sets forth he has a cannel coal mine, little thinking that it might have come down from some distant mountain ridge. The stranger, in travelling through these parts, feels astonished to hear everybody talking about the abundance of cannel coal. At the tavern where he puts up for the night he finds himself beset by a host of land speculators, who dilate in the most glowing terms on the immense value of the cannel lands they are in possession of, and, to render their description more plausible, quotes the opinion of some noted professor, who had been in the neighbourhood some years ago. The most luring baits are offered to tempt the stranger to invest. The prices vary from $3 to $30 per acre, but the question of title is generally kept on the shady side, for they are very chary of mooting this subject. The fact is that not one estate out of five, or probably ten, can produce a clear undisputed title at all. As regards the price, if they were truly cannel coal lands, the title good, and the position of the property eligibly located for working economically, $30 per acre would be quite a nominal sum, especially if there were a 3-ft. seam, or rather I should say, a seam carrying 3 ft. of cannel coal. Such, however, is not very often to be found, and when it is, its location from the river is such as to require a considerable outlay for tramroads. The cannel seams are usually the two upper ones of the measures, and in the vicinity of the navigable waters the hills are much denuded, consequently the cannel that once existed within them is either swept away, or so thinned down, broken up, or shifted by heavy slides, as to make their continuity a matter of considerable doubt; we must, therefore, look for the regular seams in the next range of hills. These lie back from the river from one to three miles, and the only method of communication is by running a line of tramroads up the creeks and ravines to the mines. This, however, is not a matter of great consideration when their construction is placed in the hands of those who understand the laying out of the works and conducting colliery operations, but a very serious one under injudicious management, which many of our London friends who have expended money here know to their cost. There is, however, immense wealth embedded in and below these forest hills, as every one who has carefully examined them affirm, but the way of rendering it profitable to the capitalist the experience of the past ten years has failed to determine. That it can, and very shortly will, be done I entertain not the least doubt, but the system hitherto pursued has to be entirely changed. Companies must place their affairs in the hands of practical men, capital must be devoted to its legitimate course, and they must ascertain the probable end of their work before they commence. The right plan is a very simple and perfectly safe one; it may appear a little more costly at the onset, but its final result on the right side admits of no doubt. There are some excellent men in this county who, if provided with the necessary means, and left untrammeled by the inexperienced dictum of boards of directors, would long ere this have developed the resources of this magnificent coal field; but they have been cramped by both, hence the present uncertain state of the matter. Kanawha, however, may soon look for better times. There are men now coming here of experience, science, and capital, both English, French, and American; they, as a body, are not to be bribed by the land jobbers, or their opinions influenced by pecuniary considerations; they already well know there is a fine field open for *bona fide* business. By close attention to the object in view their labours will be amply rewarded; honesty of purpose they know to be their best policy. Misrepresentation of the value of these mineral lands, or the non-representation of the impediments in the way of making them valuable, is unnecessary, because the scope of their explorations is almost *ad infinitum*. During the past nine months I have been making a geological and topographical survey of the south-western part of the county, between the Kanawha and Coal Rivers, and which in another year will probably be extended further up the country in the same direction. My observations, therefore, for the present must be confined chiefly to those sections that have come directly under my notice; and as there has been such a large amount of capital subscribed in England, and I may truly say sacrificed in this country, without any probability of its ever being regained, I shall from time to time furnish your readers with a full description of each mining district *seriatim*.

The Kanawha River, a stream of considerable magnitude, takes its rise among the Allegany Mountains, being formed towards its head waters by a number of powerful tributaries. It is called the New River until it passes the Gauley River, and enters Kanawha county, at the confines of which may be said to be the head of navigation. It crosses the county in a north-westerly direction, and passing through Patnam county falls into the Ohio at Point Pleasant, a place of historical renown during the Indian wars. It was here the celebrated old chief Cornstalk, the white man's friend, met his death. About centrally situate is the town of Charleston, the capital of the county, a place of considerable trade, arising chiefly from the numerous salt works in its immediate vicinity; it is 60 miles from its confluence with the Ohio, and steam-boats ply daily from the Ohio up to, and 10 miles above, the town. Near Charleston are two very fine rivers, the Elk bearing away for 150 miles to the north-east, and the Coal River for about the same distance to the south-east. These two tributaries, as well as the parent stream, are subject to severe droughts during the dry summer season, which have rendered their waters unnavigable. This has been a source of great perplexity to the mining interest, and one of the present greatest obstacles to the coal trade. A charter from the Legislature has been obtained to improve the navigation of the Kanawha; careful surveys have been made by eminent engineers, and a plan submitted. It is proposed to construct immense reservoirs up in the mountains, which during winter will fill up; these are to be drawn on in the dry weather. The river is to be sluiced—that is, wing dams are to be built at intervals, to narrow the channel to about 150 ft. wide. It is considered by this means that a sufficient volume of water may be maintained throughout the year adequate to the requirements of the navigation. Active measures are now in progress to carry out this all-desirable undertaking, which, when completed, no impediment to the transportation of the minerals will be encountered; but to execute these improvements a very serious barrier presents itself, in the form of a paucity in the monetary resources of the county, coupled with a decided apathy on the part of the people for internal improvements of any kind. Now, had one-tenth part of the capital that has been lavished by outsiders in speculative or incipient mining projects during the past 10 years been expended on the river, its waters might have been made perpetually navigable, and the mines now lying idle would have been in active and profitable operation; but, like most projects in a new country, the early pioneers commenced at the wrong end, and the result is that nearly all the capital expended on the mines has been sunk, and they have now to commence afresh, and begin at the beginning—at the river. Many excellent reports on the Kanawha coal field, ably got up, have from time to time been published, but the writers have only pourtrayed the bright side of the affair. They are in the main, perhaps, about true, because the coal being of the richest quality has been satisfactorily proved, but the market is some hundreds of miles off. The distance, however, is not of so much consequence, but between the mines and the market many difficulties intervene. The most formidable are the numerous shoals that impede the present navigation, the impetuosity of the current during freshets, and scarcity of water in summer, with a great deficiency of steam-towing power and properly constructed vessels, rendering the transportation a serious business. Mining properties in the vicinity of Charleston are of much greater value at present than those 20 or 30 miles further up the river, and must be so for some years to come, unless the extension of the projected improvements should reach them, when the difference will not be of much consequence. During the past summer the river has been so low for three months that a steam-boat, only drawing 20 in. of water, has been unable to run up; but had the improvement been carried out neither steam-boat or coal barge would have been delayed a single trip. In winter the river is often frozen up for two months, but last winter, and up to the present time of this, the ice has not been thick enough to impede the navigation scarcely at all; but even should the river be closed for 8 or 10 weeks, it is a matter of little consequence, for it must be borne in mind that all the rivers in the coal regions of this country are ice-bound for four months during the year, therefore two months only should not be considered as an impediment at all. In delineating the difficulties that beset mining enterprise in this part of Western Virginia, I do not wish to become an alarmist. Our London bondholders as well as shareholders have made heavy investments, and their capital is making no returns; they would prefer probably to read a promising report from this district, but I shall endeavour to inform them of the facts as they exist, by pointing out the true cause of the difficulties. This is the end and aim of these papers, and however unpalatable to many the narration may be, I consider it a duty incumbent on me as a public writer to do it.

These mineral lands, worked as collieries alone, have failed, and will continue to fail, paying any dividend profit until the main navigation is made permanent. It now becomes a question—How is this to be done? The public will not do it; the mining companies cannot, and the mortgagees and bondholders are reluctant to make further advances. About half a million dollars are wanted—say, 100,000*l*.—to complete the work; if this is raised, and the work accomplished, who will be the recipients of the advantages? I say it will be *pro bono publico;* for the people of the State will reap immense benefits from an extensive carrying trade; the shareholders of the several mines will have their stocks rise in value, and the bondholders secure the value of their investments by the rapidly increasing value of the mineral properties. Now, the bondholders have the largest interest at stake, for theirs has been the outlay of real cash; and should, therefore, be the first to come forward and give their support to the projected works; by doing so voluntarily it would act as a stimulus to the mining companies themselves; and if a coalition of the two interests be effected, the improvements might easily and speedily be carried out.

It must not be supposed that the capital expended in this undertaking is going to be invested and sunk merely to increase the value of the landed interests; for the subscribers will be secured by bonds on the navigation, bearing interest at the rate of 7 per cent. The traffic on the river is now very considerable, and pays good interest on the capital expended, considering the very limited means the navigation board had at command; but when the river is rendered permanently navigable the returns will be immense. It is the opinion of several prominent citizens here, who are well posted in all matters connected with internal improvements, that the tolls derivable from the augmentation of the river business will not only be ample to meet the regular payment of the interest, but leave a reserve fund to extend the works, and redeem the bonded debt in a very few years; the improvement, therefore, of the Kanawha River is of the most vital importance to the mining capitalist, and until it is done mineral properties for the purpose of colliery operations alone will be of very little value.

The Measures.—In the vicinity of Charleston, to the north-east and north-west, the strata is nearly level, the rise and dip being mere gentle undulations; they consist of grey, brown, red, and white sandstone, the latter highly fossiliferous; narrow bands of blue clay-slate, beds of clay and sandy shales, thin seams of iron ore, and isolated patches of limestone; above the slates are found thin seams of very rich hematite, many stones of which I have found that will assay up to 60 per cent. in metallic iron; but the prevailing ore is the carbonate of iron found in the kidney, or nodular form, in uneven seggregated beds in a strong ferruginous sandstone. At Davis Creek, about midway between Coal and Kanawha Rivers, are two seams of coal, one of cannel, two of iron, and two of limestone, all within 300 feet above water level. I am not aware that any smelting operations as yet have been attempted other than experimental assays to ascertain the quality of the ore, these have given entire satisfaction. There is a tract of land in Trace Fork, Davis Creek, called the Hunley Iron Mine, well worthy the attention of persons desirous of investing in Kanawha mineral lands; it is of easy access, and contains coal, iron, lime, and cannel. The general contour of the country presents a series of narrow mountain ridges and ravines, varying from 300 to 500 feet in height; in these, and all above water, levels are five workable seams of coal, one a very rich bituminous, somewhat friable, two of compact splint, and two of cannel, the latter being the uppermost of the series; the bituminous, or square-jointed seam, is 3 ft. 6 in. thick, of rich quality. One splint seam, called the "twin seam," is divided into two parts by a parting of argillaceous sandstone 18 inches thick; the entire stratification, or bed, is from 12 to 15 feet, it gives 7 feet of working coal; in some places both these beds are merged into one, where the coal is found from 5 to 6 feet thick. The next splint seam is 4 feet, and in working gives about 3 feet of merchantable coal. The upper cannel seam is 4 feet, and contains about 2 ft. 6 in. of pure cannel; it is of a slaty, or partially laminated structure; it is not very good for domestic fuel, but excellent for gas and oil-making purposes, as also for steam-boat uses, as it burns entirely away in flame. The second cannel seam varies in thickness from 4 to 6 feet, and gives from 2 to 4 ft. of fine cannel; it is not always found uniform in character, but where perfect, it is a hard coal, conchoidal in fracture, very dense, black and clean, burns with a bright white flame, is very rich in oil, makes an excellent domestic fuel, particularly that part of it called the "bird's-eye cannel;" when this coal is used no other light in the room is needed, as candles or oil lamps look dim in the glare given off in its combustion. This seam is, however, a very unreliable one; in some estates it is found changed entirely, or nearly so, into bituminous coal, in others half cannel and half bituminous; it appears best, or more regular, when imbedded in shales or laminated argillaceous sandstone, and is much easier wrought. In some mines it is between two hard rocks, without any vein of clay or shale for a "bearing in," which makes it difficult to mine; in this case it is excessively hard, and breaks before the pick like a piece of black flint, but the coal is very fine, and sells at a high price: I believe it is undergoing a state of transition, and eventually would bear the same relation to common cannel as anthracite does to splint coal. The peculiar mutability in this seam gave me an infinite amount of trouble and perplexity during my surveys; I could not identify it as the same seam in different localities: at length, by a series of careful examinations, with several explorations, I discovered it entirely changed its character when passing different locations. I have, however, not as yet arrived at any satisfactory conclusion as to the cause of this variation; for the bed and roof rock appears about the same all across the country, the shales are in places thicker and more friable than others, and the sandstone a shade more indurated, but in their mineral features they are the same. I have not met with any faults, dykes, down-throws, or upheavals, to disturb the general deposition of the strata; there are numerous slides, but these are consequent on the disintegration of the valleys or ravines, and are confined to mere surface movements; bnt even if faults were found to exist, I see no reason why the seam should be metamorphosed from cannel into one of purely bituminous coal. I am still pursuing my investigations, and as the matter is one of great interest, I should like to hear from some of your correspondents if anything of the kind exists at the Boghead Mines, in Scotland, or in the blue cannel seams in Flintshire, North Wales. I find in the upper cannel seam some of the most splendid "slickensides" I ever beheld in my life; they occur in the diagonal joints; the surfaces are equal to the finest polished black marble; where they are found the coal comes out in rhomboidal blocks; the joints do not pass up through the roof, therefore if this geological phenomenon has been caused by friction it must have been produced laterally, as no break occurs in either floor or roof. The joints of the coal are exactly like the slate formation in Carnarvon, only the cleavage planes have not that uniform parallelism. If we take an average yield of the cannel seams, we may compute them safely at 4000 tons to the acre, but in some places they are giving over 9000 tons, in others less than 3000. The bituminous coal will average 16,000 tons to the acre over about two-thirds of the surface base of the mountain lands. Cannel coal is now selling on the Ohio at $4½ per ton, and the best bituminous at $2½ per ton. The mining cost may be put down at $1½ per ton, average, but that would be materially reduced if the mining companies could be persuaded to adopt modern improvements in the mode of working the mines; the time, however, has not arrived when such can be done, although we are in great hopes another year will not pass without some example being set, which when once done efficiently, others will speedily follow. Coal and cannel selling at the above prices, a good estate, properly wrought, will realise $58,000 per acre, one-half nearly being profit.

C. S. Richardson.

(To be continued in next week's Mining Journal.)

On the Metallurgy of Lead.

BY JOHN ARTHUR PHILLIPS.

[Read at the Society of Arts, on Wednesday, April 27, 1859.]

Although lead forms an essential element in a large number of minerals, the ores of this metal are, strictly speaking, far from numerous. Of these the most important is sulphide of lead, or galena. This mineral, which possesses a metallic brilliancy, and has a lighter colour than metallic lead, presents in its cleavage all the variations, from large facettes and laminæ, indicating a cubic crystallisation, to a most minutely granular structure. It is extremely brittle, and its powder presents a brilliant blackish grey appearance. The specific gravity of galena is 7·5 to 7·8, and its composition, when absolutely pure, is—Lead, 86·55; sulphur, 13·45 = 100·00.

Galena is, however, but seldom found chemically pure, as, in addition to variable quantities of earthy impurities, it almost always contains a certain amount of silver. It is usually observed that galena presenting large facettes is less argentiferous than those varieties having a closer grain, and thus finely granular steely specimens generally afford the largest amount of silver. It would appear, from recent experiments, that the silver contained in the finely-granular varieties of galena often occurs in the form of sulphide of silver, mechanically intermixed, whilst in the more flakey descriptions of this ore the sulphides of lead and silver are chemically combined. Galena occurs in beds and veins, in granite, gneiss, clay-slate, limestone, and sandstone rocks.

In Spain it is found in the granite hills of Linares and elsewhere; at Freiberg, in Saxony, it occupies veins in gneiss; in the Hartz, Bohemia, Cornwall, and many other localities, it is found in killas, or clay-slate. The rich deposits of Derbyshire, Cumberland, and the northern districts of England are in the mountain limestone; whilst at Commern, near Aix-la-Chapelle, large quantities of this ore are found disseminated in the Bunter sandstone. This mineral is frequently associated with blende, iron and copper pyrites, the carbonate and other ores of lead, and usually occurs in a gangue of sulphate of baryta, calc-spar, spathose iron, or quartz. It is also not unfrequently associated with fluor-spar.

The next most important ore of lead is the carbonate, which is a brittle mineral, of a white or greyish white colour, having a specific gravity varying from 6·46 to 6·50. Its composition is—Carbonic acid, 16·05; oxide of lead, 83·56 = 99·61.

Large quantities of this substance occur in the mines of the Mississippi Valley, in the United States of America, where they were formerly thrown away as useless, but have since been collected and smelted. Vast deposits of this substance have also been found in the Bunter sandstone, near Duren, in Prussia, and at Freyung, in Bavaria. In the two latter localities it appears to form the cement holding together the granules of quartz, of which the sandstone principally consists. These ores, which yield from 14 to 20 per cent. of metal, do not readily admit of being concentrated by washing. The sulphate of lead does not often occur in sufficient quantities to be employed as an ore of that metal. In appearance it is not unlike the carbonate, but may readily be distinguished from it by its not dissolving with effervescence in nitric acid. Its specific gravity is from 6·25 to 6·30, and its composition—Sulphuric acid, 25·65; oxide of lead, 74·05 = 99·70. This ore of lead usually results from the oxidation of galena. At St. Martin's, near the Vega de Ribaddeo, in Spain, this mineral, more or less mixed with the phosphate of lead, is found in sufficient quantities to be made, on a small scale, the subject of an especial metallurgic treatment

Large quantities of sulphate of lead ores are also annually imported into this country from the mines in Australia. These ores contain on an average 35 per cent. of lead and 35 ozs. of silver to the ton of ore, together with a little gold.

Phosphate of lead, when crystallised, usually presents the appearance of hexagonal prisms, of a bright green, brown, or yellowish colour. Its specific gravity varies from 6·5 to 7·1. This mineral is composed of a mixture of true phosphate of lead, phosphate of lime, chloride of lead, and fluoride of calcium, and usually contains about 78 per cent. of oxide of lead. In Spain it occurs in botryoidal forms, in connection with the sulphate of the same metal, and is treated in blast-furnaces for the lead it affords. The other minerals containing lead seldom occur in sufficient quantities to be of much importance to the smelter, and may, therefore, be disregarded in the present paper.

The extraction and mechanical preparation of ores is the business of the miner, and not of the metallurgist, who receives the ores from the former freed as perfectly as possible from foreign matters.

The metallurgic processes, by the aid of which lead is obtained from galena, may be divided into two classes. The first of these is founded on the following reactions:—If one equivalent of sulphide of lead and two equivalents of the oxide of the same metal are fused together, the result is three equivalents of metallic lead and one equivalent of sulphurous acid, which is evolved. This reaction is represented by the following equation:

$$PbS+2PbO=3Pb+SO^2$$

When, on the other hand, one equivalent of sulphide of lead and one equivalent of sulphate of lead are similarly treated, two equivalents of lead are obtained, and two equivalents of sulphurous acid gas evolved. Thus—

$$PbS+PbO, SO^3=2Pb+2SO^2.$$

The process, founded on the foregoing reactions, and which we will distinguish as the *method by double decomposition*, consists in roasting the galena in a reverberatory furnace until a certain amount of oxide and sulphate has been formed, and subsequently, after having intimately mixed the charge and closed the door of the furnace, causing the whole to enter into a state of fusion.

During this second stage of the operation, the reaction between the sulphides, sulphates, and oxides takes places, and metallic lead is eliminated. The roasting of the ore is, in some cases, conducted in the same furnace in which the fusion is effected, whilst in others two separate furnaces are employed. The process by double decomposition is best adapted for the richer varieties of ore, and such as are least contaminated by siliceous or earthly impurities, and is consequently that which is almost universally employed for smelting the ores of this country.

By the second method, which we will call the *process by affinity*, the ore is fused with a mixture of metallic iron, which by combining with the sulphur liberates the metallic lead. This reaction will be understood by reference to the following formula:—$PbS+Fe=Pb+FeS$.

In practice, however, metallic iron is not always employed for this purpose; cast-iron is also frequently used, and in some instances the ores of iron and hammer-slags are substituted, as are also tap-cinder and other secondary products containing a considerable percentage of this metal. None of these substances are, however, found to be so efficacious as metallic iron; since cast-iron requires to be decarburised before it can readily decompose the sulphide of lead, and the ores of iron require the introduction of various fluxes, and the consequent expenditure of an additional amount of fuel. In all cases, however, it is judicious to subject the ore to a preliminary roasting, in order to eliminate a portion of the sulphur, and thereby reduce the expenditure of iron, as well as to agglutinate the ore, and render it better adapted for its subsequent treatment in the blast furnace. I will not attempt to describe the different forms given to roasting furnaces employed for the ores treated by this process, but would remark that they frequently resemble the kilns used for the preparation of lime, while in some instances the ores are roasted in heaps, interstratified with wood or other fuel.

The method of treating ore by *affinity* is particularly adapted to those varieties that contain a considerable amount of silica, since such minerals, if treated by double decomposition, would, by the formation of oxide of lead, give rise to silicates, from which it would be exceedingly difficult to extract the metal.

English Process—Treatment by Double Decomposition.—Galena, if placed in a close vessel which protects it from the action of the air, and exposed to a gradually increasing temperature, becomes fused without the elimination of any lead taking place, but ultimately a portion of the sulphur is driven off, and a sulphide is formed, which at a very elevated temperature is volatilised without change. If, however, the vessel be uncovered, and the air allowed to act on its contents, oxygen combines with the sulphur, sulphurous acid is evolved, and the desulphuration of the mineral is slowly effected.

When galena is spread on the hearth of a reverberatory furnace, and is so placed as to present the largest possible amount of surface to oxidising influences, it will be found that the surface slowly becomes covered with a yellowish-white crust of sulphate of lead. The oxygen of the air, by combining with the two elementary bodies of which galena is composed, will evidently produce this effect. This is not, however, the only chemical change which takes place in the charge under these circumstances; oxide of lead is produced at the same time as the sulphate, or rather the formation of the oxide is prior to that of the sulphate. In fact, during the first stage of the operation of roasting sulphurous acid is evolved, the sulphur quits the lead, and a portion of that metal remains in a free state. This becomes oxidised by the air passing through the furnace, and subsequently a part of it combines with sulphuric acid, formed by the oxidation of sulphurous acid, and sulphate of lead is the result. In this way, after the expiration of a certain period, both oxide and sulphate of lead are present in the furnace.

During the early period of the roasting, when the temperature of the furnace is not very elevated, the proportion of sulphate is larger than that of the oxide formed, but in proportion as the heat of the apparatus increases, the production of oxide becomes more considerable, whilst that of the sulphate diminishes. The sulphate and oxide thus formed react in their turn on the undecomposed galena, whilst a portion of the latter, by combining with the sulphide of lead, gives rise to the formation of oxysulphides. This last compound has no action on galena, except to dissolve it in certain proportions, but is readily decomposed by the aid of carbonaceous matter. It is, therefore, evident that the addition of carbon, at this stage of the operation, will have the effect of reducing the oxide and oxysulphide of lead. Every process, then, that has for its object the reduction of lead ores by double decomposition, comprises two principal operations.—1. The reduction of galena, by the aid of heat and atmospheric air, to a mixture of sulphide, oxide, and sulphate, which mutually decompose each other, with the elimination of metallic lead.—2. The reduction of the oxysulphide by the addition of carbonaceous matter.

The Reverberatory Furnace.—The reverberatory furnace employed for the treatment of galena is composed, like all other furnaces of this description, of three distinct parts, the fire-place, the hearth, and the chimney. The hearth has to a certain extent the form of a funnel, of which the lowest point is on the front side of the furnace immediately below the middle door. The molten metal descending from every side along the inclined bottom or sole, is collected in this receptacle, and is ultimately run off by means of a proper tap-hole. This tap-hole is, during the operation, closed by a pellet of clay. The inclination of the hearth is more rapid in the vicinity of the fire-bridge than towards the chimney, in order that the liquid metal may not be too long exposed to the oxidising and volatilising influences of a current of strongly-heated air. The dimensions given to these furnaces, as well as the weight of the charge operated on at one time, vary considerably in different localities, but in the North of England the following measurements are usually employed:—The fire-grate is 5 ft. 9 in. × 1 foot 10 in., and the thickness of the fire-bridge 1 foot 6 in.; the length of the sole is 9 ft., and its average width 7 ft. The depth of the tap is about 2 ft. 6 in. below the top of the inclined sole. The height of the roof at the fire-end may be 1 foot 4 in., and at the other extremity 11 in. The introduction of the charge is in some cases effected by the doors of the furnace, whilst in other instances a hopper, placed over the centre of the arch, is made use of.

On the two sides of the furnace are placed three doors, about 11 in. × 9 in., which are distinguished as 1, 2, and 3, counting from the fire-bridge end. The three doors on the one side are known as the front-doors, whilst those on the other side are called the back-doors. Immediately beneath the door on the front side of the furnace is situated the iron pan into which the molten lead is tapped off. The bottom of this arrangement is in most cases composed of fire-bricks, covered by a layer of vitrified slags, of greater or less thickness. In order to form this bottom, the slags are introduced into the furnace, the doors closed, and the damper raised. An elevated temperature is thus quickly obtained, and as soon as the scoriæ have become sufficiently fused, they are, by means of rakes and paddles, made to assume the required form. The charge employed, as before stated, varies in almost every establishment. In the North, however, smaller charges are used than in most other localities. At Newcastle, and in the neighbourhood, the charge varies from 12 to 14 cwts.; in Wales, and near Bristol, 21-cwts. charges are treated; whilst in Cornwall, charges of 30 cwts. are not unfrequently worked. The time required for smelting a charge varies with its weight and the nature of the ores, from 6 to 24 hours. In some cases the ores are introduced raw into the furnace, whilst in others they undergo a preliminary roasting previous to their introduction. Rich ores are generally smelted without being first calcined, but the poorer varieties, and particularly those which contain large quantities of iron pyrites, are, in most instances, subjected to roasting in a separate furnace.

In order to understand more clearly the operation of smelting in furnaces of this description, we will suppose that a charge has just been tapped off, and that, after thoroughly clearing the hearth, a fresh charge of raw ores has been introduced. During the first part of the operation of roasting, which usually occupies about two hours, the doors are taken off to admit free access of air, and also for the purpose of cooling the furnace, which has been strongly heated at the close of the preceding operation. No fuel is at this period charged upon the grate, since the heat of the furnace is of itself sufficient to effect the elimination of the first portions of sulphur. The ore is carefully stirred, for the purpose of constantly presenting a fresh surface to oxidising influences, and when white fumes are no longer observed to pass off in large quantities a little coal may be thrown on the grate, and the temperature gradually elevated until the charge becomes slightly clammy and adheres to the rake. When the roasting is considered as sufficiently advanced, the smelter turns his attention to the state of the fire, taking care to remove the clinkers, and get the grate into proper condition for the reception of a fresh supply of fuel. The furnace-doors are now closed, and a strong heat is kept up for about a quarter of an hour, when the smelter examines the condition of his charge by removing one of the doors. If the operation is progressing satisfactorily, and the lead flowing freely, and passing without obstruction into the tap, the firing is continued a little longer; but when the ores have been found to have taken fire, or are lying unevenly on the bottom of the furnace, the position of the charge is changed by the use of an iron paddle. During this operation the furnace becomes partially cooled, and the reduction of temperature thus obtained is frequently found to produce decompositions, which facilitate the reduction of the charge. In the case of extremely refractory ores this alternate heating and cooling of the furnace is sometimes almost indispensable, whilst in other instances their being raked over once or twice is all the manipulation that is required.

We will suppose that four hours have now elapsed since the charging of the furnace, and that the charge has run down the inclined sole towards the tap. The smelter now examines the condition of the scoriæ, and adds a couple of shovelfuls of lime and three or four shovelfuls of small coals, the amount and relative proportions of these being regulated in accordance with the aspect of the slags. The charge is now, by means of proper tools, again raised to the breast of the furnace, and the firing continued until the charge has run down into the tap-hole. The foreman now takes his rake, and feels if any lumps remain in an unfused condition, and if he finds all to be in a fluid state, he calls his assistant from the other side, and, by the addition of a small quantity of lime and fine coal, makes the slag assume a pasty, or rather doughy, consistency. By the aid of his paddle he now pushes this compound up to the opposite side of the furnace, where it it drawn by an assistant through the back door into a trough containing water. Whilst the assistant is doing this, the foreman is busily engaged in tapping off the metal into the iron pan in front of the furnace, from which, when sufficiently cooled, it is laded out into suitable moulds. The total duration of the operation may be about six hours. To build a furnace of the above description 5000 common bricks, 2000 fire-bricks, and 2½ tons of fire-clay are required. In addition to this must be reckoned the iron work, the expense of which will be much influenced by the nature of the armatures employed and the locality in which the furnace is constructed.

The amount of fuel employed for the treatment of a ton of lead ore varies not only in relation to the richness of the mineral, but is also much influenced by the nature of the associated matrix and the calorific value of the fuel itself. The loss of metal experienced during the operation is mainly dependent on the richness of the ore treated, and the skill and attention of the foreman. In the North about 12 cwts. of coal are consumed in the elaboration of 1 ton of ore, and the loss of metal on 60 per cent. ore may be estimated at about 12 per cent., of which about 6½ per cent. is subsequently recovered from the slag and fumes. At a well-conducted smelting works, situated in the West of England, in which the average assay of the ores smelted during the year was 75½, the yield from the smelting furnaces was 68½ per cent., and the coal used per ton of ore was 13¾ cwts. The lead recovered from the slag and fumes amounted to 2¾ per cent., making the total yield of metal 71¼ per cent., and the loss on the assay produce 4½ per cent. In this establishment the men are paid from 7s. 6d. to 12s. 6d. per ton of lead, in accordance with the nature of the ores operated on.

In one establishment the process before described is somewhat varied. The charge employed is 21 cwts. This is run down and tapped off at the expiration of six hours, and about nine pigs of 1¼ cwt. each usually obtained. A second charge of 21 cwts. is then dropped in, and, as soon as it is roasted, mixed with the slags of the former operation. The whole is then run down in the ordinary way, the slags drawn, and the lead tapped off in nine hours. The produce of the second, or double charge, is from 14 to 15 pigs. If the ores are difficult to flow, 16 to 16½ hours are required for the two charges. A small quantity of black slag from the slag hearth is employed for drying up.

Slag Hearth.—The various slags obtained from the different operations of lead smelting are divided into two classes. Those which do not contain a sufficient amount of metal to pay for further treatment are thrown away as useless, whilst those in which the percentage of lead is sufficiently large are treated with the slag hearth. This consists of a small blast-furnace, having the form of a rectangular prism, about 25 inches in height, 22 in. in breadth, and 33 in. in depth. The bottom is composed of a thick cast-iron pan, which is made to incline slightly from the tuyere towards the breast of the furnace. Cast-iron bearers are placed on each side of the iron plate, and on these is supported the fore-hearth, which consists of two stout plates of cast-iron. A space of about 5 in. is thus left between the front and bottom of the furnace, and an additional height of 2½ in. is obtained by placing between them a row of fire-bricks laid on their flat. The slags escaping through the opening in the breast of this arrangement sometimes flow into a cistern of water sunk in the earth. This causes the slag to divide into small fragments, and thus adapts them for the process of washing, when it is intended to subject them to this operation. Before starting a furnace of this description, its bottom is filled to a depth of 1 foot or 15 in. with small spongy cinders rather closely packed together, and which reach to within 4 or 5 in. of the orifice of the tuyere; the breast pan is also filled with cinders, which are intended to act as a kind of filter in the separation of metallic lead from the slags. The furnace is frequently lighted by the aid of a small quantity of peat, and when this has become fairly ignited, some good hard coke is thrown in, and as soon as it appears to be sufficiently inflamed, a stratum of grey slag, or any other substance to be treated, is introduced. From this time, the hearth is supplied with alternate strata of fuel and slag. The lead obtained from the slag hearth is, from the high temperature at which it is produced, always harder, and, therefore, inferior in quality to that procured directly from the ores in the reverberatory furnace, and this process is consequently never applied to the treatment of products that admit of being economically worked by the furnace before described. In addition to being employed for the reduction of slags, this apparatus is sometimes applied to the elaboration of ores of low produce, in the treatment of which the object sought is rather the extraction of the silver they contain than the reduction of the largest possible amount of lead.

Instead of being blown by a cold-blast, these furnaces are sometimes supplied with heated air. When smelting with cold air, it is often found difficult to proportion the quantity of slag or other substance operated on, so as to preserve the nose or cone of slag which forms at the end of the tuyere from growing too long, to the prejudice of the operation. When the substance operated on is poor for metal, and very refractory, it frequently happens that the smelter is obliged to break the nose, or introduce some very fusible substance in order to melt it off. By the introduction of hot air this inconvenience is removed, since by increasing or lowering the temperature of the blast the nose may be allowed to lengthen or shorten, according as the nature of the slags may require. The temperature found to answer best is from 250 to 300 deg. Fahr.; since when it is heated to from 500 to 600 deg. it is found impossible to form a nose of sufficient length to convey the blast to the front of the hearth, and, therefore, the back, which is expensive to rebuild, is quickly destroyed. The advantage to be derived from the use of the hot-blast will be evident from the result of two experiments which were tried some years since: 28 tons of slag, smelted with cold-blast, consumed 392 cubic feet of air per minute. Labour cost, 3*l.* 7s. 8d.; coke, 7 tons, at 24s. 6d. = 11*l.* 19s. 2d.: 35 tons of similar slag, smelted with hot-blast, consumed 300 cubic feet of air per minute. Labour cost, 3*l.* 7s. 8d.; coke, 5 tons 17 cwts., at 24s. 6d., 7*l.* 3s. 4d.; turf for heating ores, 11 loads, 1s. 8d., 18s. 4d. = 11*l.* 9s. 4d. From which it will be seen that with one-quarter part less ores a quarter part more slag was melted per week, and a saving in expense of 10s. effected. The loss of lead experienced in smelting by the slag hearth is, however, very great, even under the most favourable circumstances; and it has, consequently, of later years been gradually superseded by the Castillian furnace, which will be shortly described. Many large and well-conducted establishments still, however, continue to employ the slag hearth, and, when well constructed and skilfully managed, the loss arising from volatilisation may be considerably reduced.

Scotch Hearth.—Instead of the reverberatory furnace, the Scotch hearth may frequently be employed with advantage for the treatment of lead ores of good produce. This consists of a rectangular cavity, lined with cast-iron, and of which the dimensions vary in different localities, although it is frequently made about 2 ft. square. The bottom is also of cast-iron, and is surrounded by a ledge, about 5 in. in height, with the exception of the side nearest the work-stone, which is of iron, and may be about 20 in. in breadth. This plate is made to have a fall of about 6 in. on its whole breadth; its upper side rests on the hearth bottom, or, in some instances, is united with it, only forming one casting. On the back edge of the furnace bottom is placed a prism of cast-iron, called a back-stone, and on this rests the nozzle of the tuyere, over which is again placed another block of the same metal, called a pipe-stone; and on this is placed another back-stone, which completes this side of the hearth. Along the two lateral edges of the hearth bottom are laid two prismatic castings, called bearers, which project slightly over the upper edge of the work-stone. Above these bearers is a prism of cast-iron, called a fire-stone, the space at each end being closed by cubes of cast-iron, called key-stones. Before the work-stone, and set in masonry, is the lead pot, into which the melted metal, as it issues from the hearth, is conducted by an oblique channel sunk beneath the surface of the iron plate. To prevent the escape of fumes into the smelting-house, the whole is covered by a hood of arched bricks, which is provided with a sheet-iron front. The blast introduced through the tuyere is regulated by a throttle valve, and the brickwork is consolidated and bound together by heavy iron straps, kept in their places by screw bolts passing through the masonry. The ores treated in the Scotch hearth are usually roasted in a separate furnace, for the purpose of effecting their partial desulphuration and oxidation before undergoing the process of smelting. At the termination of every shift, a quantity of ore remains on the hearth in a semi-reduced state, called "browse," and is more or less mixed with fragments of coke and clinker, from which it is afterwards roughly separated.

To commence a new shift, the cavity of the furnace is filled with peat cut into blocks; those at the back are heaped up without any kind of sides, but those towards the front are arranged in the shape of a wall. The blast is now turned on, and an ignited fragment of peat thrown immediately before the nozzle, which quickly communicates combustion to the whole mass. On the top of this a few shovelfuls of coal are subsequently placed, and the browse resulting from the preceding operation is then charged on the top of the ignited mass, and shortly afterwards a portion of the molten matters in the internal basin is drawn on to the work-stone. The grey slag is now removed, and thrown on one side of the furnace, and the browse, thus freed from slag, again returned to the hearth, with the addition of a little coal. If, as is sometimes the case, it has not been properly freed from slag, and therefore exhibits a disposition to fuse, it must be hardened by the addition of a small quantity of quicklime, which dries up the materials in such a way as to facilitate the subsequent extraction of the lead. When, on the contrary, the ore is found too refractory, a small quantity of lime, or of lime and fluor-spar, is added, but in this case a less amount of lime is employed, as it is intended as a flux, and not as a drier of a too fusible slag. The slag thus obtained still contains a notable amount of lead, and is subsequently treated in the slag hearth. When the whole of the browse has been thrown back into the hearth, a few shovelfuls of roasted ore are distributed over it; before doing this, however, the scoriæ are removed, and a lump of peat is placed before the tuyere, which not only prevents any of the mineral from entering the nozzle, but also, from its porosity, seems to equalise and distribute the air through the mass. After another interval of about 20 minutes, the contents of the hearth are again drawn out on the work-stone, and another portion of metallic lead obtained. The grey slag is removed, and another lump of peat placed before the tuyere; the browse, together with a proper quantity of coal and quick lime, are again thrown upon the fire, and on the top is laid a fresh supply of roasted ore. The Scotch hearth will, in accordance with the nature of the ore treated, yield from 1 to 2 tons of metallic lead per shift, and usually affords softer metal than the reverberatory furnace.

In an establishment in the North, where the Scotch hearth is employed, and in which the ores treated contain on an average 73 per cent of metal, the following results are obtained:—The lead reduced at the first fire amounts to 60 per cent., but 3·20 per cent. are subsequently obtained from the slags, and 6·91 per cent. from the fumes, making the ultimate loss on the assay produce 2·90 per cent. The materials employed for the elaboration of 1 ton of ore are as follows:—

Coals for smelting ..... Cwts.	1 2 4	3 1 15
Coals for calcining	1 3 11	
Peat or tarf		0 3 0
Lime		0 2 0
Total cwts.		4 2 15

To construct an ore-hearth 2000 common bricks and the same quantity of fire-bricks are required, together with about 1½ tons of fire-clay.

Castilian Furnace.—Within the last few years a blast furnace has been introduced into the lead works of this country, which possesses great advantages over every other description of apparatus which has been hitherto employed for the treatment of lead ores of low produce. This apparatus, although first employed in Spain, was, I am informed, invented by an Englishman (Mr. W. Goundry) who was employed in the reduction of rich slags in the neighbourhood of Carthagena. This furnace is circular, usually about 2 ft. 10 in., or 3 ft. in diameter, and is constructed of the best fire-bricks, so moulded as to fit together, and allow all the joints to follow the radii of the circle described by the brickwork. Its usual height is 8 ft. 6 in., and the thickness of the masonry invariably 9 inches. In this arrangement the breast is formed by a semi-circular plate of cast-iron, furnished with a lip for running off the slag, and has a longitudinal slot, in which is placed the tapping-hole. On the top of this cylinder of brickwork a box-shaped covering of masonry is supported by a cast-iron framing, resting on four pillars, and in this is placed the door for feeding the furnace, and the outlet by which the various products of combustion escape to the flues. The lower part of this hood is fitted closely to the body of the furnace, whilst its top is closed by an arch of 4½ inch brickwork laid in fire-clay. The bottom is composed of a mixture of coke-dust and fire-clay, slightly moistened, and well beaten to the height of the top of the breast-pan, which stands nearly 3 ft. above the level of the floor. Above the breast-pan is an arch, so turned as to form a sort of niche, 18 in. in width, and rather more than 2 ft. in height. When the bottom has been solidly beaten to the required height, it is hollowed out so as to form an internal cavity, communicating freely with the breast-pan, which is filled with the same material, and subsequently hollowed out to a depth slightly below the level of the internal cavity. The blast is supplied by three water tuyeres, 3 in. in diameter at the smaller end, 5½ in. at the larger, and 10 in. in length. Into these the nozzles are introduced, by which a current of air is supplied by means of a fan or ventilator, making about 800 revolutions per minute. The blast may be conveniently conducted to the nozzles through brick channels formed beneath the floor of the smelting-house. The ores treated in this furnace ought never to contain more than 30 per cent. of metal, and when richer, must be reduced to about this tenure by the addition of slags and other fluxes. In charging this apparatus, the coke and ore are supplied stratum super stratum, and care must be taken to so dispose the coke as not to heat too violently the brickwork of the furnace.

In order to allow the slags which are produced to escape freely into the breast-pan, a brick is left out of the front of the furnace at the height of the fore hearth, which, for the purpose of preventing the cooling of the scoriæ, is kept covered by a layer of coke dust or cinders. From the breast-pan the slags flow constantly off over a spout into cast-iron wagons, where they consolidate into masses, having the form of truncated pyramids, of which the larger base is about 2 feet square. As soon as a sufficient

of lead has accumulated in the bottom of the furnace, it is let off lateral lead pot, by removing the clay stopper of the tap-hole situated ot the breast-pan, and after being properly skimmed it is laded moulds. When in addition to lead the ore treated likewise contains tain portion of copper, this metal will be found in the form of a matt ior on the surface of the leaden bath. This, when sufficiently solidi- is removed, and after being roasted is operated on for the copper it ains. The wagons in which the liquid slag runs off are frequently to traverse small railways, by which when one mass has been re- d its place may readily be supplied by an empty wagon. When r cold the casings of the wagons are turned over, and the blocks of are easily made to drop out. In addition to the facility for transport ed in this way, one of the great advantages obtained by this method anipulation arises from the circumstance that should the furnace at ime run lead or matt without it being detected by the smelter, the h of it will be collected at the bottom of the block, from which, when d, it may be readily detached.

working these furnaces, care must be taken to prevent flame from ning at the tunnel-head, since, provided the slags are sufficiently d, the cooler the apparatus is kept the less will be the loss of metal ough volatilisation. In addition to the greatest attention being paid to working of the furnace, it is necessary, in order to obtain the best re- s, that all establishments in which this apparatus is employed should rovided with long and capacious flues, in which the condensation of fume takes place previous to arriving at the chimney-shaft. These should be built 3 feet in width, and 6 feet in height, so as readily admit of being cleaned, and are often made of great length. The t of the fumes so condensed amount to many hundreds, and in some ances thousands per annum. In order to be advantageously worked hese furnaces, the ores should be first roasted, and subsequently agglo- rated into masses, which, after being broken into fragments of about the of the fist, and mixed with the various fluxes, are charged as before ribed. In an establishment in which the average assay produce of the tal ore for lead is 42½ths, the furnace yield is 38$\frac{11}{12}$ths, and the weight uke employed to effect the reduction 22 per cent. of the roasted ore n on. The mixture charged into the furnace, in this instance, is posed of 100 parts of roasted ore, 42 parts of slags from a previous ation, 8 parts of scrap iron, and 7 parts of limestone. Each furnace s off about 7 tons of roasted ore in the course of 24 hours; the weight slags run off is about double that of the lead obtained, and the matt re- ved from the surface of the pan is nearly 5 per cent. of the lead pro- ed. The ores treated in this establishment consist of galena, much ed with spathose iron, and are, therefore, somewhat refractory. A fur- e of this kind requires for its construction about 1200 segmental fire- cks, and the same number of ordinary fire-bricks of second quality.

The desulpuration of the ores to be treated in these furnaces may be ef- ed either by the aid of an ordinary reverberatory roasting furnace, or in gs, or properly constructed kilns. The kilns best adapted for this pur- e consist of rectangular chambers, having an arched roof, and provided h proper flues for the escape of the evolved gases, as well as a wide door charging and withdrawing the ore to be operated on. Each of these mbers is capable of containing from 25 to 30 tons of ore; and in order harge it a layer of faggots and split wood is laid on the floor, and this, having been covered by a layer of ore, about 2 feet in thickness, is ted, care being at the same time taken to close, by means of loose k-work, the opening of the door to the same height. When this first has become sufficiently ignited, a fresh stratum of ore, mixed with a le coal or charcoal, is thrown upon it, and when this layer has in its turn ome sufficiently heated, more ore is thrown on. In this way more ore is m time to time added, until the kiln has become full, when the orifice of doorway is closed by an iron plate, and the operation proceeds regularly d without further trouble until the greater portion has become eliminated. is usually happens at the expiration of about four weeks from the time first ignition, and the brick-work front is then removed, and the ores ken out, and after being mixed with proper fluxes, passed through the st-furnace. The proportion of wood necessary for the roasting of a ton ore by this means must necessarily depend on the composition of the erals operated on; but with ores of the description above-mentioned, d in a neighbourhood where wood is moderately cheap, the desulphur- on may be effected at a cost of about 5s. per ton.

CALCINING.—The lead obtained by the various processes above described erally contains a sufficient amount of silver to render its extraction of ch importance; but, in addition to this, it is not unfrequently associated h antimony, tin, copper, and various other impurities, which require to removed before the separation of the silver can be effected. This ope- ion consists in fusing the hard lead in a reverberatory furnace of pe- liar construction, and allowing it to remain, when in a melted state, ex- sed to the oxidising influences of the gases passing through the apparatus. this treatment the antimony, copper, and other impurities become oxi- sed, and on rising to the surface of the metallic bath are skimmed off, d removed with an iron rake. The hearth of the furnace in which this eration is conducted consists of a large cast-iron pan, which may be 8 ft. length, 5 ft. 6 in. in width, and 10 in. in depth. The fireplace, which 1 foot 8 in. in width, has a length equal to the width of the pan, and is parated from it by a fire-bridge 2 feet in width. The height of the arch the bridge end is 1 foot 4 in. above the edge of the pan, whilst at the ter extremity it is only about 8 in. The lead to be introduced into the n is first fused in a large iron pot fixed in brick-work at the side of the rnace, and subsequently laded into it through an iron gutter adapted for at purpose. The length of time necessary for the purification of hard d obviously depends on the nature and amount of the impurities which contains; and, consequently, some varieties will be sufficiently improved the expiration of twelve hours; whilst in other instances it is necessary continue the operations during three or four weeks. The charge of hard d varies from 8 to 11 tons.

When the metal is thought to be in a fit state for tapping, a small por- n taken out with a ladle, and poured into a mould used for this purpose, found on cooling to assume at the surface a peculiar crystallised appear- ce, which, when once seen, is readily again recognised. As soon as this pearance presents itself an iron plug is withdrawn from the bottom of e pan, and the lead run off into an iron pan, from which it is subsequently aded into moulds. The items of cost attending the calcination of 1 ton hard Spanish lead in the North of England are about as follows:—Wages, 1s. 11·2d.; coals, 2·7 cwts., 4·7d.; repairs, &c., 0·5d. = 2s. 4·4d. he construction of a furnace of this description requires 5000 common icks, 3500 fire-bricks, and 2 tons of fire-clay.

CONCENTRATION OF THE SILVER.—This process is founded on the cir- mstance first noticed in the year 1829 by the late H. L. Pattinson, of ewcastle-on-Tyne, that when lead containing silver is melted in a suit- ble vessel, afterwards slowly allowed to cool, and at the same time kept nstantly stirred, at a certain temperature near the melting point of lead, etallic crystals begin to form. These, as rapidly as they are produced, nk to the bottom, and on being removed are found to contain much less ver than the lead originally operated on. The still fluid portion, from hich the crystals have been removed, will at the same time be propor- nally enriched. This operation is conducted in a series of eight or ten st-iron pots set in a row, with fire-places beneath. These are each capable containing about 6 tons of calcined lead; and on commencing an operation at quantity of metal containing, we will suppose, 20 ozs. of silver per ton introduced into a pot (say, No. 4) about the centre of the series. This, hen melted, is carefully skimmed with a perforated ladle, and the fire im- ediately withdrawn. The cooling of the metal is also frequently hastened throwing water upon its surface, and whilst cooling it is kept constantly gitated by means of a long iron stirrer, or slice. Crystals soon begin to their appearance, and these as they accumulate and fall to the bot- m are removed by means of a large perforated ladle, in which they are ell shaken, and afterwards carried over to the next pot to the left of the orkman. This operation goes on continually until about 4 tons of crys- ls have been taken out of the pot No. 4, and have been placed in pot o. 5, at which time the pot No. 4 may contain about 40 ozs. of silver to e ton, whilst that in No. 5 will only yield 10 ozs. The rich lead in o. 4 is then laded into the next pot, No. 3, to the right of the workman, nd the operation repeated in No. 4, on a fresh quantity of calcined lead. this way calcined lead is constantly introduced, and the resulting poor ad passes continually to the left of the workman, whilst the rich is pass- g towards his right. Each pot in succession, when filled with lead of its roper produce for silver, is in its turn crystallised, the poor lead passing the left of the workman, and the enriched lead to his right. By this ethod of treatment, it is evident that the crystals obtained from the pots the left of the workman must gradually be deprived of their silver, whilst e rich lead passing to his right becomes continually richer. The final result is that at one end of the series the poor lead contains very little silver, whilst at the other an exceedingly rich alloy of lead and silver is obtained.

The poor lead obtained by this process should never contain more than 12 dwts. of silver per ton, whilst the rich lead is frequently concentrated to 500 ozs. to the ton. This rich lead is subsequently cupelled in the refining furnace. The ladle employed for the removal of the crystals, when manual labour is made use of, is about 16 in. in diameter, and 5 in. in depth, but when cranes are used much larger ladles are easily managed. A form of crane has been invented by Mr. J. Sparks, which effects considerable economy of labour. When, during the operation of crystallisation, the ladle becomes chilled it is dipped into a small vessel containing lead of a higher temperature than that which is being worked, and known by the name of a temper-pot. The pot containing the rich lead is often called the No. 1 pot; in some establishments, however, the last pot in which the pure lead is crystallised obtains this appellation. The cost of crytallising 1 ton of calcined Spanish lead, in the establishment quoted when treating of calcination, is as follows:—Wages, 9s. 5·4d.; coals (4 cwts.), 8·4d.; repairs, 2·5d.: total, 10s. 4·5d. The erection of nine 6-ton pots requires 15,000 common bricks, 10,000 fire-bricks, 160 feet of quarles, 80 fire-clay blocks, and 5 tons of fire-clay. In some establishments 10-ton pots are employed, and where cranes are made use of they are found to be advantageous.

REFINING.—The extraction of silver contained in the rich lead is conducted in a cupel forming the bottom of a reverberatory furnace called a refinery. In this operation the litharge produced, instead of being absorbed by the substance of the cupel, is run off in a fluid state, by means of a depression called a gate. The size of the fire-place varies with the other dimensions of the furnace, but is usually nearly square, and in an apparatus of ordinary size may be about 2 ft. by 2 ft. 6 in. This is separated from the body of the furnace by a fire-bridge 18 inches in breadth, so that the flame and heated air pass directly over the surface of the cupel, and from thence escape by means of two separate apertures into the main flues of the establishment. The cupel or test consists of an oval iron ring, about 5 in. in depth, its greatest diameter being 4 ft. and its lesser nearly 3 ft. This frame, in order to better support the bottom of the cupel, is provided with cross-bars about 4½ in. wide, and ½ in. in thickness. In order to make a test, this frame is beaten full of finely-powdered bone-ash, slightly moistened with water, containing a small quantity of pearlash in solution, which has the property of giving consistency to the cupel when heated. The centre of the test, after the ring has been well filled with this mixtnre, and solidly beaten down, is scooped out with a small trowel, until the sides are left 2 in. in thickness at top, and 3 in. at the bottom, whilst the thickness of the sole itself is about 1 in. At the fore part or wide end of the test the thickness of the border is increased to 6 in., and a hole is then cut through the bottom, which communicates with the openings or gates by which the liquid litharge makes its escape. The test, when thus prepared, is placed in the refinery furnace of which it forms the bottom, and is wedged to its proper height against an iron ring firmly built in the masonry. When this furnace is first lighted, it is necessary to apply the heat very gradually, since if the test were too strongly heated before it became perfectly dry it would be liable to crack. As soon as the test has become thoroughly dry, it is heated to incipient redness, and is nearly filled with the rich lead to be operated on, which has been previously fused in an iron pot at the side of the furnace, and beneath which is a small grate, where a fire is lighted.

The melted lead, when first introduced into the furnace, becomes covered with a greyish dross; but on further increasing the heat, the surface of the bath uncovers, and ordinary litharge begins to make its appearance. The blast is now turned on, and forces the litharge from the back of the test up to the breast, where it passes over the gate, and falls through the aperture between the bone-ash and the ring into a small cast-iron pot running on wheels. The air, which is supplied by a small ventilator, not only sweeps the litharge from the surface of the lead towards the breast, but also supplies the oxygen necessary for its formation. In proportion as the surface of the lead becomes depressed by its constant oxidation, and the continual removal of the resulting litharge, more metal is added from the melting-pot, so as to raise it to its former level; and in this manner the operation is continued until the lead in the bottom of the test has become so enriched as to render it necessary that it should be tapped. The contents of the test are now so far reduced in volume that the whole of the silver contained in the rich lead operated on remains in combination with a few hundred weights only of metal, and this is removed by carefully drilling a hole in the bone-ash forming the bottom of the test. The reason for the removal of the rich lead is to prevent too large an amount of silver from being carried off in the litharge, which is found to be the case when lead containing a very large amount of that metal is operated on.

When the rich lead has been thus removed, the tapping-hole is again closed by a pellet of bone-ash, and another charge immediately introduced. As soon as the whole of the rich lead has been subjected to cupellation, and has become thus further enriched, the argentiferous alloy is itself similarly treated, either in a fresh test, or in that employed for the concentration of the rich lead. The brightening of pure silver at the moment of the separation of the last traces of lead indicates the precise period at which the operation should be terminated, and the blast is then turned off, and the fire removed from the grate. The silver is now allowed to set, and as soon as it has become hardened, the wedges are removed from beneath the test, which is placed on the floor of the establishment. When cold, the silver plate is detached from the test, and any adhering particles of bone-ash removed by the aid of a wire brush.

A test furnace of ordinary dimensions requires for its construction about 2000 common bricks, 2000 fire-bricks, and 1½ ton of fire-clay. A furnace of this kind will work off 4 pigs of lead per hour, and consume 4 cwts. of coal per ton of rich lead operated upon. The cost of working a ton of rich lead in the neighbourhood of Newcastle, containing on an average 400 ozs. of silver per ton, is as follows:—

Refiner's wages	£0 4 2·1	Pearl-ash	£0 0 3·5
Coals, 4 cwts.	0 0 6·8	Bone-ash, 17·3 lbs.	0 3 1·0
Engine wages	0 1 7·0	Repairs	0 0 5·0
Coals, 5 cwts.	0 0 8·7		
Total			£0 10 10·1

REDUCING.—The reduction to the metallic state of the litharge from the refinery, the pot dross, and the mixed metallic oxides from the calcining furnace, is effected in a reverberatory apparatus, somewhat resembling a smelting furnace, except that its dimensions are smaller, and the sole, instead of being lowest immediately below the middle door, gradually slopes from the fire-bridge to near the flue, where there is a depression, in which is inserted an iron gutter, which constantly remains open, and from which the reduced metal flows continuously into an iron pot, placed by the side of the furnace for its reception, and is subsequently laded into moulds. The litharge, or pot dross, is intimately mixed with a quantity of small coal, and is charged on that part of the hearth immediately before the fire-bridge. To prevent the fused oxide from attacking the bottom of the furnace, and also to provide a sort of hollow filter for the liquid metal, the sole is covered by a layer of bituminous coal. The heat of the furnace quickly causes the ignition of this stratum, which is rapidly reduced to the state of a spongy cinder. The reducing gases present in the furnace, aided by the coal, mixed with the charge itself, cause the reduction of the oxide, which assuming the metallic form flows through the interstices of the cinder, and ultimately finding its way into the depression at the extremity of the hearth flows through the iron gutter into the external cast-iron pot. The surface of the charge is frequently, during the process of elaboration, turned over with an iron rake, for the double purpose of exposing new surfaces to the action of the furnace, and also to allow the reduced lead to more readily flow off. Fresh quantities of litharge, or pot dross, with small coal are from time to time thrown in, in proportion as that already charged disappears, and at the end of the shift, which usually extends over 12 hours, the floor of cinder is broken up, and after being mixed with the residual matters in the furnace is withdrawn. A new floor of cinders is then introduced, and the operation commenced as before. A furnace of this kind, having a sole 8 ft. in length and 5 ft. in width, will afford from litharge about 4½ tons of lead in 24 hours, and will consume 20 cwts. of coal.

The dross from the calcining pan, when treated in a furnace of this description, should be previously reduced to a state of fine division, and intimately mixed up with small coal and a soda-ash. In many cases, however, the calcined dross is treated in the smelting furnace. The hard lead obtained from this substance is again taken to the calcining furnace, for the purpose of being softened. The expense of reducing 1 ton of litharge may be estimated as follows:—Wages, 2s. 6d.; coals (3 cwts.), 5·2d.; repairs, 1·6d. = 3s. 0·8d. In the establishment from which the foregoing data were obtained, the cost of slack delivered at the works was only 2s. 11d. per ton, which is cheaper than fuel can be obtained in the majority of the lead mills of the country. In North Wales the cost of small coal is generally about 4s., and at Bristol 5s. 6d. per ton. The total cost of elaborating 1 ton of hard lead, containing 30 ozs. of silver per ton, in a locality in which fuel is obtained at the low price above quoted, is nearly as follows:—

Calcining	£0 2 4·4	Slags	£0 0 5·0
Crystallising	0 9 6·5	Bone-ash, &c.	0 0 7·0
Refining	0 0 9·2	Transport, &c.	0 1 1·0
Reducing (pot dross & litharge)	0 1 0·8	Management, taxes, and interest of plant	0 5 10·0
Calcined dross	0 0 8·0		
Total			£1 2 3·9

One hundred tons of hard lead treated gave:—Soft lead, 94·90; black dross, 3·72; loss, 1·38 = 100·00. On comparing the expense of each operation, as given in the foregoing abstract, with the amounts stated as the cost of each separate process, they will be found to be widely different; but it must be remembered that the whole of the substances elaborated is far from being subjected to the various treatments described. In order, therefore, to give an idea of the relative proportions which are passed through the several departments, I may state that in an establishment in which the ores are treated in the Castillian furnace the following are the results obtained:—100 parts of raw ore yielded—Roasted ore, 85; hard lead, 42; soft lead, 36; rich lead, 9; dross and litharge re-treated, 18½. The importance of this branch of our metallurgic industry will be gathered from the following tabular statements, chiefly derived from Mr. Robert Hunt's valuable statistics:—

TABLE I.

Table showing the Quantity of Lead Ore raised and smelted, Average Metallic Yield of Ore per cent., and Ratio of Lead produced in various parts of the United Kingdom, during ten years ending 1857.

Years.	England.		Wales.		Ireland.		Scotland.		Isle of Man.		Total.	
	Lead ore.	Lead.	Lead ore.	Lead.	Lead ore.	Lead.	Lead ore.	Lead.	Lead ore.	Lead.	Lead ore.	Lead.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1848	44,538	30,142	16,905	11,172	1,912	1,186	2,588	1,736	2,521	1,665	77,864	54,853
1849	60,124	41,168	19,711	13,389	2,739	1,653	1,421	957	2,836	1,835	86,821	58,702
1850	63,565	44,462	21,093	14,876	2,893	1,746	3,117	2,124	2,175	1,218	92,845	64,426
1851	64,102	45,103	19,314	14,813	3,222	1,929	3,113	2,140	2,560	1,402	92,311	65,387
1852	62,411	43,813	18,379	13,708	4,482	3,222	3,499	2,381	2,415	1,835	91,187	64,959
1853	59,342	41,897	17,131	12,870	3,909	2,452	2,799	1,919	2,460	1,629	85,641	60,967
1854	64,796	44,996	18,130	13,267	3,069	2,210	2,783	1,879	2,600	2,137	90,848	63,979
1855	66,270	46,244	18,206	13,672	2,403	1,732	1,587	1,159	2,573	2,726	92,041	65,833
1856	74,489	52,868	19,873	14,791	2,484	1,802	1,931	1,417	2,218	2,641	101,997	73,129
1857	68,800	48,356	21,455	16,124	2,399	1,407	1,891	1,351	2,656	2,998	96,821	69,266
Total	638,137	448,039	189,597	138,733	29,827	19,941	33,699	16,463	27,204	18,926	907,486	641,101
Av. metallic yield p. ct. of ore	70·2		73·1		66·0		69·4		69·1		70·6	
Ratio of lead produced	69·9		21·7		3·0		2·5		2·1		=100	

TABLE II.

Estimated value of lead and silver consumed in Great Britain, 1857:—

Lead and silver produced in the United Kingdom	£1,670,353	
Silver imported, 846,569 ozs.	232,806 = £1,903,159	
Lead exported	Tons 22,397	
Lead imported	„ 12,768 = 9,629	211,838
Value consumed		£1,691,321

TABLE III.

Silver produced from ores raised in Great Britain for four years, ending 1857:—

	1854.	1855.	1856.	1857.
England	Ozs. 419,924	439,983	481,909	417,343
Wales	67,051	57,521	62,357	58,097
Ireland	18,096	7,252	3,700	3,071
Scotland	5,426	4,947	5,289	4,206
Isle of Man	52,262	51,597	60,382	48,016
Total	562,659	561,300	613,637	530,733
Value, at 5s. 6d. per ounce	£154,730	£154,357	£168,750	£146,501

Market value of lead produced in the United Kingdom in 1857	£1,523,852
Ditto of silver	146,501
Total	£1,670,353

It would be evidently impossible to comprise within the limits of a single paper a description of the whole of the various processes employed in different parts of the world for the reduction of lead from its ores; and I have, consequently, confined myself to an exposition of the general routine of the operations commonly practised in this country. In doing this it has been my endeavour to furnish reliable data as to the expenses and losses incurred in each operation; and although it would have been easy to have multiplied examples, want of space has prevented my doing so. It is in the treatment of ores of good produce that the reverberatory furnace and Scotch hearth are to be preferred; but for working minerals of a low percentage the blast furnace may generally be substituted with advantage. The slag hearth, from the amount of fuel consumed and loss experienced, is a somewhat expensive apparatus, and might, in many cases, be advantageously exchanged for the Castillian furnace. It is well-known that the losses which take place in this branch of metallurgy are, from the volatility of the metal operated on, unusually large. In those establishments, however, in which due attention is paid to fluxes and a proper admixture of ores, as well as the condensation of the fumes, a great economy is effected. In lieu of long and extensive flues, condensers of various descriptions have from time to time been introduced, but in most instances the former have been found to be more efficient.

After the reading of the paper, which was illustrated by specimens of the various ores of lead, and the different processes were elucidated by a complete series of diagrams, drawn to a scale of 3 in. to 1 foot, there was a very interesting discussion, in which Messrs. Robt. Hunt (the Chairman), John Phillips, Warrington, Hyde Clarke, and others, took part. This we shall give in detail in a Supplement with next week's Journal.

PATENT SAFETY-CAGE.—Amongst the drawings exhibited at the Society of Arts is one of a safety-cage invented by Mr. R. Aytoun, of Edinburgh, and which has already been described in the *Mining Journal*. The actual winding-rope or chain is connected at its lower end by a ring or hook, to which again is attached a double chain connected diagonally to the cage by spring-clipping levers. The longer arms of the levers are formed with lateral projections embracing the main vertical guides in the shaft, the relations of the parts being such that so long as the jamming-levers are kept in a horizontal position the cage can work freely up and down the guides; but when they are thrown out of the horizontal line by the breakage of the rope or otherwise the levers jam firmly upon each face of the guide, and the descent of the cage is arrested.

ALGER'S ELLIPTICAL FURNACE.—Mr. C. C. Alger provisionally specified a patent for the application of his new principle to a cupola furnace, but no complete specification was filed, probably because the invention contains no novelty which would not be covered by his former patent.

COAL-BURNING LOCOMOTIVES.—The invention of Mr. Peter Brotherhood consists in the interposition between the fire-box and ordinary tubes of a combustion chamber connected with the fire-box by one or more tubes surrounded by water, having an opening for the admission of atmospheric air, and communicating with the combustion chamber through a number of small tubes, by which means the atmospheric air is brought into contact with the flame and gas entering the combustion chamber. A disc of fire-clay is placed at a short distance from the air tubes in the combustion chamber; on striking against the disc the flame and inflammable gases spread over the whole of the air tube surface, prevent smoke, increase heat, and economise fuel.

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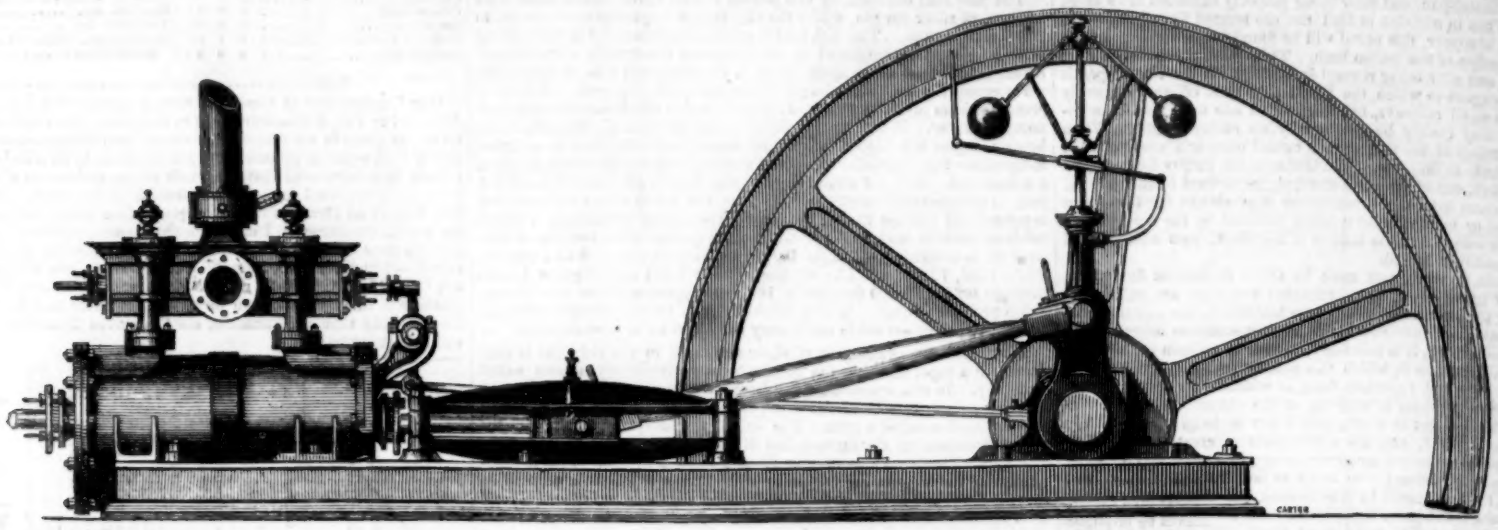

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1 Pair Sugar Tongs, best quality.	0 3 6	0 5 6	0 6 0	0 7 0
1 Pair Fish Carvers, best quality.	1 0 0	1 10 0	1 14 0	1 18 0
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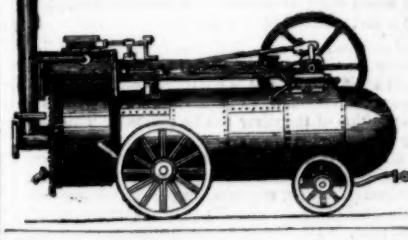

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